static adjustment *to* life rather than dynamic adjustment *of* life. Plato, indeed, recognized "the sad but inescapable fact that while you can teach an ignorant slave the beautiful but apparently useless science of geometry, Pericles himself could not teach his own sons how to live the good life." As I. Kant has reminded us, "Man is not only an animal that knows, but one that acts and knows." It has been well stated, however, by J. H. Randall and G. Buchler in their *Philosophy: An introduction* that "philosophy cannot cultivate a faith, only experience can do that . . . It can clarify the faith that is already in him." By the term faith, of course, I do not mean belief in spite of evidence, nor the will to believe in absence of evidence, but rather expectation resulting from evidence. It is my personal conviction that the liberal sciences can deepen one's spiritual faith and thus contribute to education for world citizenship.

The liberal sciences are important in education not only because of their contribution to the inadequacy of common sense, not only because they make possible a bridge to the humanities, but most of all because they exhibit a faithfulness of nature.

PALEONTOLOGY.—*The pelecypod family Corbiculidae in the Mesozoic of Europe and the Near East.* RAYMOND CASEY,[1] Geological Survey of Great Britain. (Communicated by Alfred R. Loeblich, Jr.)

(Received October 14, 1955)

The family Corbiculidae, formerly called Cyrenidae, is an important element of the recent pelecypod fauna, its members being widely distributed in the rivers and estuaries of the world. Its fossil representatives are well known in the Tertiary and Upper Cretaceous, but when we recede to earlier Mesozoic time the record of the family becomes obscure. Although the literature on the fresh-water and brackish-water deposits of the Lower Cretaceous and Jurassic contains many references to *Cyrena* (= *Corbicula*), most of these on subsequent investigation have proved to relate to genera outside the scope of the Corbiculidae. Nevertheless, in the Far East true Corbiculidae, differing but little from Tertiary and Recent members of the family, were in existence already in the Lower Jurassic (Suzuki and Oyama, 1943). If these Lower Jurassic Corbiculidae are regarded as the ancestors of subsequent members of the family there arises the problem that has always faced the evolutionist when dealing with fresh- or brackish-water organisms, namely, that of explaining the perpetuation and migration of genera denied the relative freedom of movement of marine stocks. As a solution to this problem, the possibility of the Corbiculidae being a polyphyletic group which was from time to time replenished from independent marine sources should not be lightly dismissed. The purpose of the present paper is to draw attention to some Corbiculidae in the Lower Cretaceous of Europe and the Near East that show unmistakable evidence of derivation from a marine genus, *Eocallista*, of the Upper Jurassic. Since these forms can have no connection with earlier Corbiculid developments, they afford strong support for the hypothesis of polyphyletic origin of the Corbiculidae.

This paper was prepared in connection with a study of Mesozoic Corbiculidae for the *Treatise on invertebrate paleontology*, and I am indebted to Dr. L. R. Cox of the British Museum (Natural History) and to Dr. F. W. Anderson of the Geological Survey of Great Britain for access to specimens in their charge.[2]

[1] Published by permission of the Director, Geological Survey of Great Britain.

[2] Repositories of cited specimens are indicated by the symbols G.S.G.B. (Geological Survey of Great Britain) and B.M. (British Museum (Natural History)).

SYSTEMATIC DESCRIPTIONS

Family Corbiculidae (correction of Corbiculadae) Gray, 1847 (= Cyrenidae Gray, 1840)

Genus **Eocallista** H. Douvillé, 1921

Type species.—*Venus brongniarti* Roemer, Upper Jurassic (Portland beds), Europe; by original designation (H. Douvillé, 1921: 124).

Generic characters.—Of small to medium size (rarely exceeding 30 mm in length), trigonal-ovate or cuneiform, posterior slope evenly rounded or flattened, a feeble umbonal ridge in the young; umbones moderately prominent, situated subcentral to well forward; beaks small, prosogyrous; no definite lunule or escutcheon; surface smooth or with subdued concentric ornament; pallial line truncated below the posterior adductor scar but not sinuate. Hinge of early cyrenoid type, formula:

$$\frac{\text{A I (III) 3a 1 3b P I}}{\text{A II 2a 2b 4b P II}};$$

3a strongly prosocline; 1 triangular, slightly prosocline, the apex rounded, directed toward the beak but removed from the cardinal margin; 3b acutely triangular, strongly opisthocline, obscurely bifid; 2a formed by a thin, tapering, bent-up and slightly projecting portion of the lateral A II, strongly prosocline; 2b triangular, orthocline, situated directly below the beak, the apex curved forwards to to contact 2a; 4b slender, gently curved or straight, strongly opisthocline; anterior laterals more or less straight; P I well removed from the cardinals, elongate; P II formed by a thickening of the hinge plate below the projected shell margin.

Remarks.—There has been some uncertainty as to the systematic position of *Eocallista*. Most authors have followed H. Douvillé in regarding it as a primitive member of the Veneridae, though Cox (1947: 142) has included it in the Arcticidae (= Cyprinidae), from which family, via *Isocyprina*, it may well have been derived. The lack of a pallial sinus is against its association with the Veneridae, despite a strong resemblance to the Lower Cretaceous venerid *Resatrix*. It is now allocated to the Corbiculidae because of its obvious connections with the brackish-water genus described below as *Filosina*.

Subgenus **Eocallista** s.s.

Subgeneric characters.—Hinge with the cardinal teeth entire, except for an obscurely bifid 3b; anterior laterals short, no A III.

Remarks.—*Eocallista* s.s. first appears in the Middle Jurassic (Bathonian) but is best known from its occurrence in the Portland beds of the Upper Jurassic. A number of Corallian and Kimmeridgian species, such as "*Cyprina*" *tancrediformis* Blake and Hudleston and "*Cyprina*" *implicata* de Loriol, formerly referred to *Eocallista*, have since been assigned to *Procyprina* and *Isocyprina* (Casey, 1952: 136, 144). The absence of *Eocallista* from these strictly marine, ammonite-bearing strata in Britain and its occurrence in beds (e.g., Sharp's Hill beds, Upper Estuarine series, Forest Marble, Chert bed at top of Portland Roach and Portland Basal Shell Bed) where ammonites are either absent or very rare suggest that the genus may, while still marine, have preferred waters of less than normal salinity.

Hemicorbicula, n. subg.

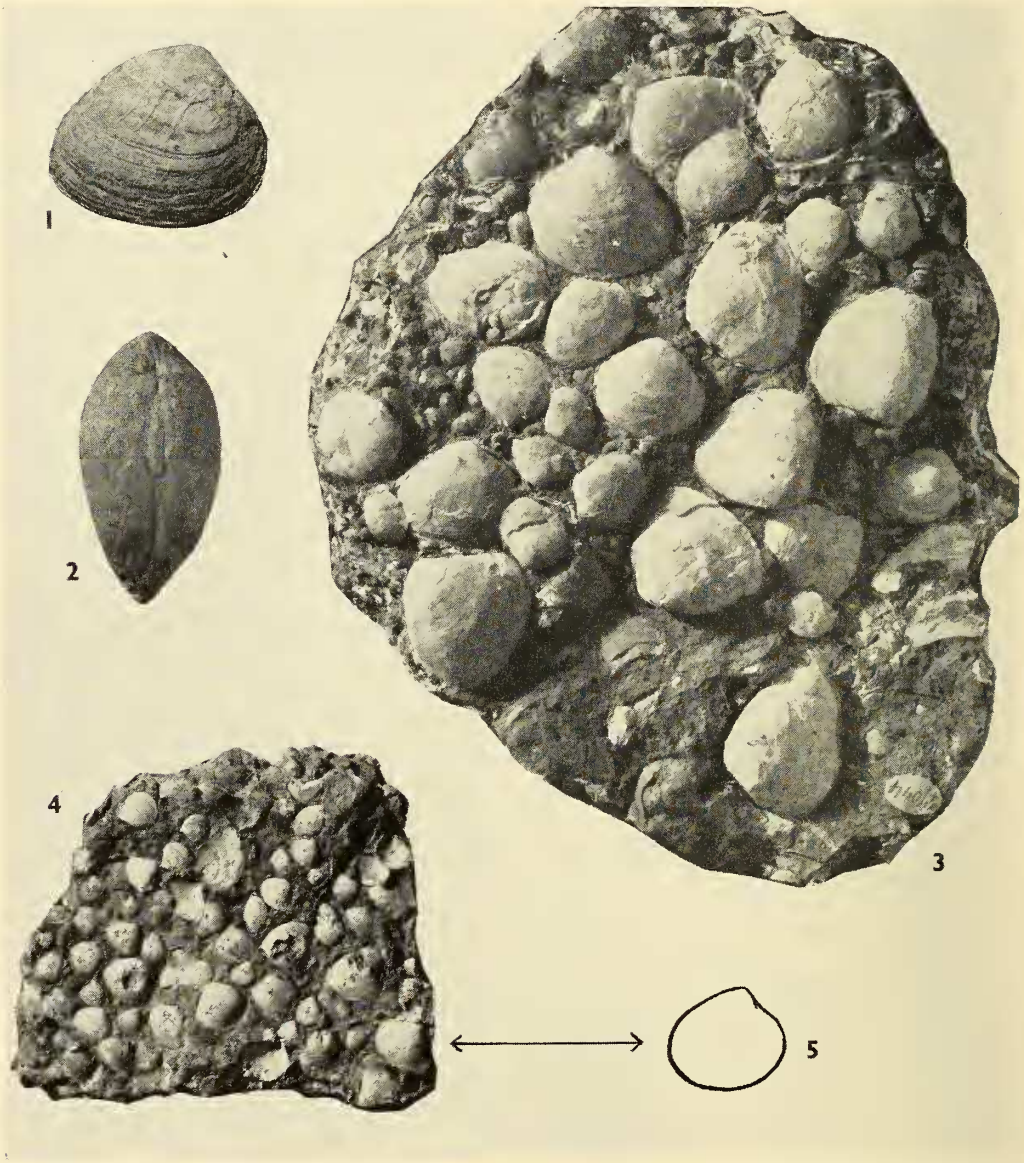
Type species.—*Cyclas parva* J. de C. Sowerby, Upper Jurassic (Purbeck beds), Europe (= *Astarte socialis* d'Orbigny).

Subgeneric characters.—Small *Eocallista* (usually less than 10 mm in length); hinge with tooth 1 bifid or concave, 2a entire or feebly grooved at the base, 2b bifid, 4b grooved along the crest; anterior laterals long, with development of a rudimentary A III.

Designation of a neotype for Cyclas parva *J. de C. Sowerby.*—Sowerby's species was founded on material from the Purbeck beds of the Vale of Wardour, Wiltshire, submitted to him by W. H. Fitton, whose collection, formerly in the Geological Society of London, is now in the Geological Survey of Great Britain. The specimen figured by Sowerby (in Fitton, 1836: pl. xxi, fig. 7) does not appear to have survived, but there is abundant topotype material available from which the characters of the species may be determined. It is proposed to make application to the International Commission on Zoological Nomenclature for recognition of the specimen indicated in Figs. 4 and 5 as neotype of *Cyclas parva*. This specimen is part of a small limestone block which is composed largely of molds of this little pelecypod. It was obtained by Fitton from the Purbeck Beds of Ladydown, Vale of Wardour, and is registered in the Geological Survey of Great Britain as Geol. Soc. Coll. 2698.

Remarks.—*Hemicorbicula* is well represented in the brackish-water beds of the Middle Purbeck of southern England, especially in the Upper Building Stones and *Corbula* beds, where it is often sufficiently abundant to be a rock builder. Its usual faunal associates are *Neomiodon*, *Corbula*, and *Modiolus*. It has not been found either in the

marine intercalations of the Purbeck or in the purely fresh-water facies of that formation. Under the synonymous name *Astarte socialis* d'Orbigny, *E. (H.) parva* has been described from the topmost part of the "Porltandien" of the Bas Boulonnais, northern France, where it occurs in myriads, associated with ostracods, just as in the Vale of Wardour. The internal characters of *Cyclas parva* have



FIGS. 1–5.—MESOZOIC CORBICULIDAE

1–3, *Filosina gregaria*, n. gen., n. sp., Lower Cretaceous (Upper Wealden beds), southern England: 1, Side view of holotype, Wealden shales (12 feet below Perna bed), Atherfield Point, Isle of Wight (G.S.G.B. no. 86446) × 1; 2, dorsal view of immature paratype showing ligament, Wealden Shales, Sandown, Isle of Wight (G.S.G.B. no. Zm 1825) × 2; 3, paratype slab showing typical field occurrence, Weald Clay, Sevenoaks, Kent (B.M. no. L 47044) × 1.

4–5, *Eocallista* (*Hemicorbicula*) *parva* (J. de C. Sowerby), Upper Jurassic (Middle Purbeck beds), Ladydown, Vale of Wardour, Wiltshire: 4, Slab showing typical field occurrence. The specimen in the bottom righthand corner, indicated by the arrow, is here designated neotype (G.S.G.B. no. Geol. Soc. Coll. 2698) × 1; 5, outline drawing of neotype, × 2.

not been investigated previously and its relationship to the marine genus *Eocallista* has therefore passed unnoticed, as also its identity with d'Orbigny's *Astarte socialis*. To *Hemicorbicula* I would also refer *Anisocardia intermedia* de Loriol, another French "Portlandien" species which is also found in the English Middle Purbeck (e.g., G.S.G.B. 86640).

Morphologically, *Hemicorbicula* is intermediate between *Eocallista* s.s. and *Filosina* and could with equal propriety have been classified as a subgenus of the latter.

Filosina, n. gen.

Type species.—*F. gregaria*, n. sp., Lower Cretaceous (Wealden Shales and Weald Clay), southern England.

Generic characters.—Trigonal-ovate or subrectangular, rounded in front, more or less truncated behind; umbones subcentral or anterior, moderately prominent; beaks small, prosogyrous; evenly inflated or with weak posterior angulation; no lunule or escutcheon; surface smooth or with concentric riblets; nymphs finely rugose; pallial line truncated below the posterior adductor scar but not sinuate. Hinge cyrenoid with long, subequal laterals, faintly cross-striated; formula:

$$\frac{\text{A I III 3a 1 3b P I}}{\text{A II 2a 2b 4b P II}},$$

cardinal teeth similar to those of *Hemicorbicula* in the young, but in the adult less widely splayed, with 2a and 1 separated from the laterals and with a tendency to become entire.

Remarks.—Species from the Upper Wealden (Wealden Shales and Weald Clay) of southern England hitherto referred to *Cyrena*, *Cyclas* or *Neomiodon* belong properly to *Filosina*. In these beds *F. gregaria* and *F. membranacea* (J. de C. Sowerby) are the principal members of a recurrent brackish-water assemblage in which *Paraglauconia*, *Ostrea*, *Corbula*, and *Nemocardium* are also represented. This assemblage dominates the topmost beds of the Wealden and presumably foreshadows the marine transgression of the Aptian which put an end to Wealden conditions. In the Aptian of the Lebanon *Filosina* is represented by *Corbicula* (*Batissa?*) *hamlini* Whitfield. Here it is associated with a rich, predominately marine, fauna, though the presence of both *Filosina* and *Eomiodon* in this fauna indicates waters of decreased salinity. It is interesting to note that Whitfield's species was assigned doubtfully to *Eocallista* by Vokes (1946: 193).

Filosina differs from *Corbicula* and *Batissa* and most other members of the Corbiculidae in its relatively weak posterior lateral dentition; the tooth P II is merged into the margin and P III is absent altogether. This alone provides contrast with such Cretaceous corbiculids as *Fulpia* Stephenson and *Dentonia* Stephenson of the Cenomanian of North America. The genus or subgenus *Veloritina* Meek, based on *Cyrena durkeei* Meek of the Bear River Cretaceous of Wyoming, has a similar hinge but is a gibbous-trigonal form with deeply depressed lunular and ligamentary areas; it appears to be congeneric with the species from the Middle Jurassic of Japan (Tetori series) for which Suzuki and Oyama have proposed the name *Mesocorbicula*. A subelliptical or subcircular outline and deep ascending pallial sinus distinguish *Tetoria* Kobayashi and Suzuki of the same horizon. The Japanese "Wealden" forms which these last authors have assigned to *Paracorbicula* and *Isodomella* are also distinct from *Filosina*; the former is obliquely ovate to subcircular and has crenulated posterior lateral teeth and a sinuated pallial line; the latter is distinguished chiefly by its subtrapezoidal shape and long, wedge-shaped cardinal teeth. The Japanese Lower Cretaceous *Cyrena radiostriatus* Yabe and Nagao, for which Matsumoto has introduced the subgeneric name *Costocyrena*, is incompletely known but its combination of concentric and radial ornament claims taxonomic separation from typical *Polymesoda* and the other corbiculid genera here discussed. The genus *Neomiodon*, with which *Filosina* has been generally confused, belongs to a different family and is distinguished mainly by possessing only two cardinal teeth in each valve and duplicate posterior laterals in the right valve.

Filosina gregaria, n. sp.

Figs. 1–3; 6 c–d

Type material.—Holotype G.S.G.B. 86446, Wealden shales (12 feet below Perna bed), Atherfield Point, Isle of Wight; paratypes G.S.G.B. 86445, 86447, Wealden Shales, Atherfield Point, Isle of Wight; G.S.G.B. Lm 1825, Wealden Shales, Sandown, Isle of Wight; G.S.G.B. 86441–86443, Weald Clay, Staplehurst, Kent; G.S.G.B. 86444, Weald Clay, Tonbridge, Kent; G.S.G.B. FD 1760–1762, Weald Clay, Marden, Kent; G.S.G.B. L 1892, Weald Clay, Railway Cut, South of Redhill Station, Surrey; B.M. 47044, Weald Clay, Sevenoaks, Kent.

Specific characters.—Trigonal-ovate *Filosina* of moderate and even inflation, up to 30 mm in length; umbo placed at anterior three-quarters of length; anterodorsal area only feebly excavated; anterior margin strongly convex, forming a continuous curve with the moderately convex ventral margin; posterodorsal margin gently arched, steeply sloped to meet the low, truncated, or feebly rounded posterior extremity.

Dimensions of holotype.—Length 28 mm, height 25 mm, thickness (single valve) 6 mm.

Remarks.—For a century and a quarter this species has been confused with Sowerby's *Cyclas media*, and under that name or as *Cyrena media* or *Neomiodon medius* it has been frequently cited in the literature. Sowerby's species, the type of *Neomiodon*, is a Purbeck shell, smaller, relatively elongate, and with a steep, flattened posterior slope. Limestones composed of the compacted valves of *Filosina gregaria* form pavements along the foreshore at Atherfield Point and at Sandown, Isle of Wight, where the Wealden shales are washed by the sea. The species occurs similarly in myriads on various horizons in the Weald Clay of Kent, Surrey, and Sussex. *Cyclas membranacea* J. de C. Sowerby, also referable to *Filosina*, is a

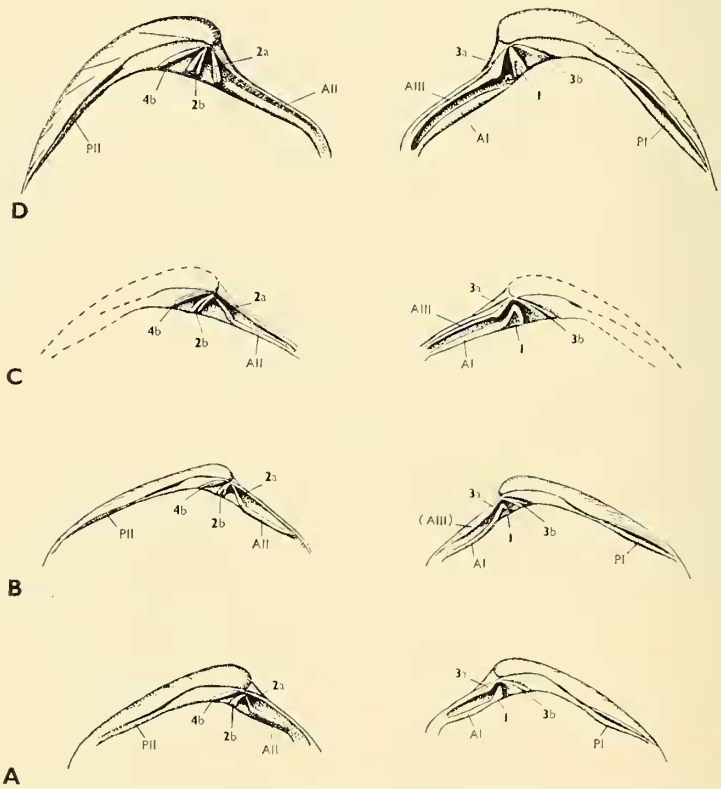


FIG. 6.—HINGES OF *Eocallista* S.S., *Hemicorbicula*, N. SUBGEN., AND *Filosina*, N. GEN.

A. *Eocallista* (*Eocallista*) *pulchella* (de Loriol), Upper Jurassic (Portland beds; chert bed at top of Portland Roach), Portland, Dorset, southern England. L.V., G.S.G.B. no. Y 1261; R.V., G.S.G.B. no. Y 1271; both enlarged × 4.5.

B. *Eocallista* (*Hemicorbicula*) *parva* (J. de C. Sowerby), Upper Jurassic (Middle Purbeck beds), between depths of 678 feet and 678 feet 4 inches in D'Arcy Exploration Company's no. 1 Ashdown Well, Crowborough, Sussex, southern England. L.V., G.S.G.B. no. 86428; R.V., G.S.G.B. no. 86428; both enlarged × 5.

C. *Filosina gregaria*, n. gen., n. sp. Immature paratypes. Lower Cretaceous (Upper Wealden beds; Weald Clay), Marden, Kent, southern England. L.V., G.S.G.B. no. FD 1760; R.V., G.S.G.B. no. FD 1761; both enlarged × 5.

D. *Filosina gregaria*, n. gen., n. sp. Adult paratypes. Lower Cretaceous (Upper Wealden beds), southern England. L.V. Weald Clay, Staplehurst, Kent, G.S.G.B. no. 86441; R.V. Wealden Shales, Isle of Wight, B.M. no. L 63055; both slightly restored from other specimens and enlarged × 1.5.

smaller species with strongly convex ventral margin and more distinctly truncated posterior end. *F. hamlini* (Whitfield) is easily distinguished by its subrectangular outline and stronger inflation.

Hinge preparations have been made in a series of specimens of this species showing growth stages of 6 mm upward. These have revealed important ontogenetic changes in dentition. Between 6 and 12 mm length the dentition of *F. gregaria* differs from that of *Hemicorbicula* only in the following features: the anterior laterals are longer, there is a well developed A III, and the tooth 2a is invariably grooved, albeit feebly. With increase in growth, the cardinal teeth become less widely splayed, and in the adult the teeth 2a and 1 become distinctly separated from the parent laterals. Different specimens show varying degrees of loss of the grooves on the cardinals; in general those of 4b and 2a are the first to disappear; 1 and 3b usually retain some vestige of a sulcus or concavity; 2b remains bifid throughout ontogeny.

Nemetia, n. gen.

Type species.—*Platopis triangularis* Whitfield, Lower Cretaceous (Aptian), Syria.

Generic characters.—Subtrigonal, moderately inflated shells, without lunule or escutcheon; umbones fairly prominent, beaks small and prosogyrous; a sharp angulation of the shell demarcates a flattened posterior area; surface smooth or concentrically ornamented; hinge similar to that of immature *Filosina* but with entire cardinals.

Remarks.—The discovery by Vokes that his designation of *P. plicata* Whitfield as the type species of *Platopis* was invalid (Vokes 1952) leaves the taxon centered around *P. plicata* and *P. triangularis* in need of a name. The name *Nemetia* is here proposed for this taxon, to which is referred *Platopis triangularis* Whitfield, *P. plicata* Whitfield, *P. whitfieldi* Vokes, and *Eocallista beiha* Vokes, all from the Aptian of the Lebanon. The close relationship of *Nemetia* and *Eocallista* has been recognised by Vokes (1946, 1952). The principal features distinguishing *Nemetia* from *Eocallista* are the more trigonal outline and strong posterior angulation of the valves in the former genus; it also possesses longer anterior laterals and a distinct A III, and the tooth 1 is implanted in the centre of the hinge with its apex close to the cardinal margin. Externally, there is great resemblance to the carinated forms of the genus *Pronoella* (Arcticidae).

THE EVOLUTION OF FILOSINA AND NEMETIA

Since the three taxa *Eocallista* s.s., *Hemicorbicula*, and *Filosina* appear on successive geologic horizons and show progressive modifications in dentition, they are considered to form an evolutionary series. This series is regarded as part of a lineage converging toward the brackish-water *Corbicula* from an origin in the Arcticidae, a purely marine family. It shows a gradual elongation and strengthening of the anterior lateral dentition, while the cardinal teeth progress from the early cyrenoid to the fully cyrenoid position and acquire the grooving characteristic of the Corbiculidae. Only minor features of dentition distinguish the end term of this series—*Filosina*—from *Corbicula* itself, whose recorded range extends from the Middle Jurassic to Recent (Suzuki and Oyama, 1943: 140). The arcticid affinities of *Eocallista* have been acknowledged (Cox, 1947: 142; Casey, 1952: 134) and it is significant that a member of the Arcticidae, *Isocyprina*, gave rise in Lower Cretaceous times to the venerid *Resatrix*—a homoeomorph of *Eocallista*. When describing this genus *Resatrix*, I pointed out how its evolution from *Isocyprina*, via the Upper Jurassic subgenus *Vencricyprina*, was achieved by deepening of the pallial sinus and by movement of the cardinal teeth from the cyprinoid to the cyrenoid position. In the process of transition the anterior part of the tooth 2b ($2b_1$) was atrophied and eventually eliminated, though its remnants are still discernible in the early forms of *Resatrix*. Turning to *Eocallista*, we find that already in the Middle Jurassic it possessed an early cyrenoid hinge with no trace of a separate structure $2b_1$. The pallial line remained unchanged, exhibiting a posterior truncation but no definite sinus. These facts demonstrate the independent origin of *Eocallista* and *Resatrix*, but there are so many similarities in the evolution of *Resatrix* and that of the *Eocallista-Filosina* series that a common ancestry of both stocks in *Isocyprina* seems probable. The same range of variation of external form is found in both stocks; in each case the posterior end of the shell becomes broadly truncated in the latest known members of

the lineage (compare *F. hamlini* Whitfield sp., as figured by Vokes, 1946, pl. 8, fig. 20, and *Resatrix* (*Dosiniopsella*) *cantiana* Casey, 1952, pl. 8, fig. 3). The movements of the cardinal teeth into the fully cyrenoid position are precisely analogous in both cases. The hinge of the young *Filosina* (Fig. 6 C) shows many points of similarity with that of Barremian-Aptian species of *Resatrix* s.s.—the widely splayed cardinals, grooved 4b, partially bifid 2a, and the attachment of 2a and 1 to the laterals (see Casey, 1952, fig. 76). The adult *Filosina* (Fig. 6 D) on the other hand, shows a stage of hinge development attained by a Lower Albian subgenus of *Resatrix*, *Dosiniopsella* (see Casey, 1952, fig. 75); the angle of radiation of the cardinal teeth is perceptibly narrowed; 2a and 1 are severed from the laterals, and the tooth 4b is entire. In both *Filosina* and *Resatrix* the laterals are cross-striated, but in the former genus these striations, like the nymphal rugosities, have been observed only in a few specimens of unusually good preservation, and it is not known at what stage they were introduced into the lineage.

In the case of the Aptian genus *Nemetia* evidence of derivation is less satisfactory owing to lack of record during Purbeck and Wealden times. Its similarity in hinge characters to both *Eocallista* and *Filosina* suggests that it formed part of the same evolutionary plexus.

The importance of the arcticid genus *Isocyprina*, which is represented in the marine faunas from the Upper Triassic to Lower Cretaceous, has been the subject of previous comment (Casey, 1952: 134). It appears to have played the role of a slowly evolving parent stock from which diverged successive offshoots with more advanced hinge structures. *Eocallista* and *Resatrix* are believed to be two such offshoots which pursued a more or less parallel course. The former, first recognized in the Middle Jurassic, was adaptable to waters of decreased salinity and in the Lower Cretaceous, now modified to *Filosina*, successfully colonized the brackish-water swamps of the Upper Wealden and left its record in the quasi-marine Aptian deposits of Syria. *Nemetia* is conceived of as a divergence from *Filosina;* it probably lived under rather more saline conditions than did the Wealden species of *Filosina*, approximating to those favored by *Eocallista* s.s., as is suggested by the preponderance of marine genera among its faunal associates. *Resatrix* appears at the base of the Cretaceous; it is the earliest known representative of the Veneridae and is strictly marine.

The subsequent history of *Filosina* and *Nemetia* and their relationship to later members of the Corbiculidae is not known. But if the views here expressed on their phylogeny are correct, two facts of great importance in the study of pelecypod evolution are indicated—(1) a correlation between hinge structures and ecologic station and (2) the polyphyletic origin of the family Corbiculidae. Thus, despite the fact that the order of appearance of the two families is the reverse of that formerly supposed, the generalization that the Corbiculidae was "derived, in different degrees of removal, from the exclusively marine Veneridae" (Cooke, 1895: 15) may not be wholly incorrect. It is probable that venerid genera like *Resatrix*, *Calva* and *Dosiniopsis* represent a morphologic type which throughout Cretaceous and Tertiary times was a potential source of Corbiculidae.

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